WGC Technical Database – an immediate success!

The WGC Technical Database (see *Gold Bulletin*, vol 35 (**3**) 2002, page 100) went live on the WGC web site in August. It has proved an immediate hit with scientists and industrialists wanting to keep up-to-date with the latest science and technology of gold. Statistics show about 35,000 visits were made in September and this grew to almost 50,000 visits in October, a month-on-month increase of 14%. Updated quarterly, this searchable Database will next be updated at the end of March.

Gold Bulletin is also available on the WGC website and is receiving around 9,000 visits per month. The Technical Database will be found at www.gold.org/value/sci_indu/techdatabase

Highlights from Recent Literature

Note:
A more comprehensive list of literature and patents, updated quarterly, will be found in the searchable **Technical Database** on the World Gold Council website, **www.gold.org** under the Science and Industry domain.

1 Analytical

1.1 Biotinylation of Colloidal Gold Particles Using Interdigitated Bilayers: A UV-Visible Spectroscopy and TEM Study of the Biotin-Avidin Molecular Recognition Process

The surface modification of colloidal gold particles with biotin groups using a technique based on interdigitated bilayers is described by N. Lala, A.G. Chittiboyina, S.P. Chavan and M. Sastry from the National Chemical Laboratory, Pune, India, *Colloids and Surfaces, A: Physicochemical and Engineering Aspects* 2002, **205**(1-2), 15-20. The biotinylation of the colloidal particles is accomplished by a two-step process. The first step involves the self-assembly of a close-packed primary monolayer of octadecanethiol (ODT) mols. on the colloidal particle surface. Thereafter, a secondary monolayer of alkylbiotin molecules is self-assembled on the ODT-capped gold colloidal particles by interdigitation of the alkyl groups of the biotin molecules with the hydrocarbon chains of the primary monolayer. The resulting biotinylation of the colloidal particles is checked by the high-affinity biotin-avidin interaction, which leads to crosslinking of the colloidal particles and an easily measurable change in the optical properties of the sol. This approach may be important for the incorporation of molecules with functional groups that become inactive due to modification of the molecule with colloidal particle surface-anchoring groups such as thiol groups and thus shows scope for development.

1.2 Formation of Third Phase and Spectroscopic Research of Loading Organic Phases in Gold Extraction

The formation of the third phase during the gold extraction from cyanide solution by quaternary ammonium, tetradecyldimethylbenzylammonium chloride (TDMBAC) was studied by the198Au tracer method.(J.Z. Jiang, W.J. Zhou, H-C. Gao, J.W. Chen and J.G. Wu from the College of Chemistry and Molecular Engineering, Peking University, Beijing, *Guangpuxue Yu Guangpu Fenxi*, 2002, **22**(3), 396-398). The microstructure of the organic phases was investigated by FTIR, 31P-NMR. With increasing gold concentration, aggregations were formed in the gold-loaded organic phase. With further increasing gold concentration the organic phase turned into two layers. Gold, water, and tri-Bu phosphate (TBP) were mainly in the down organic phase. In the down layer, distinct O-H stretching vibration peak was found by FTIR; the frequency of P=O stretching vibration shifted to the low frequency; 31P-NMR chem. shift was markedly shifted to the high frequency field. The radius of aggregation was measured by dynamic laser scattering (DLS) method.

1.3 An Electrochemical and In Situ Raman Investigation of the Electrodeposition of Gold from a Sulphite Electrolyte

A. Fanigliulo and B. Bozzini from the University of Lecce, Italy, *Transactions of the Institute of Metal Finishing*, 2002, **80**(4), 132-136 studied the Gold electrodeposition from Gold(I) sulfite 0.05 M and 0.5 M baths at pH 6 by cyclic voltammetry and in situ Raman spectroscopy. Two electroplating regimes were identified: at low cathodic potentials a form of cathodic passivation occurs, whereas a charge-transfer controlled reduction occurs at high cathodic potentials.

The combination of electrochemical and spectroscopic methods reveals that the cathodic passivation is related to the formation of an S film at the electrode, due to the simultaneous reduction of Gold(I) and sulfite. This film can be either oxidized electrochemically or reduced by polarizing the cathode at potentials at which HS- forms. Gold electroplating from slightly acidic sulfite baths is of commercial interest, but the efficiency of the process and the quality of the deposits can be impaired by the concurrent

cathodic formation of S. This phenomenon can nevertheless be avoided, even in the absence of the additives proposed in the patent literature, provided that the plating conditions are suitably selected.

1.4 Determination of Gold by Flame Atomic Absorption Spectrophotometry after Enrichment and Separation with Tri-N-Octyl Amine Cotton

The preparation of tri-n-octyl amine cotton and the condition of its adsorption of gold as well as gold desorption method are described by A-L. Zou and S-L. Deng from the Department of Mineral Engineering, Central South University, Changsha, Peoples Republic of China, *Guangpu Shiyanshi*, 2002, **19**(4), 451-454. The FAAS method is employed for gold detection. The detection range of this method is 0.5-40g/t. Its relative standard deviation is 2.3%. The method was applied to the detection of gold in chalcopyrite, and its result agreed with that of the traditional polyurethane from enrichment method. This method is quick and simple with good separation effect.

1.5 The Effects of Mercury Adsorption on the Optical Response of Size-Selected Gold and Silver Nanoparticles

T. Morris, H. Copeland, E. McLinden, S. Wilson and G. Szulczewski from the Department of Chemistry, University of Alabama, AL, USA, *Langmuir*, 2002, **18**(20), 7261-7264, studied the adsorption of Hg atoms onto gold and silver nanoparticles by optical spectroscopy, transmission electron microscopy, XPS, and energy-dispersive X-ray analysis. Mercury adsorption induces a blue shift of the surface plasmon mode of gold and silver nanoparticles. Two trends are observed in the UV-visible spectra. First, silver particles experience a larger blue shift than gold particles (given the same particle size and Hg surface coverage). Secondly, smaller gold and silver particles experience a greater blue shift than larger particles. The authors have calculated the UV-visible absorption spectra using a core/mercury(shell) model and found good agreement between the experimental results and theoretical calculations. The results suggest the basis for a novel colorimetric assay for Hg.

2 Catalysis

2.1 Catalysis by Gold Nanoparticles

Gold catalysts have superior activity in CO and other oxidations at low temps. Both a small (approximately 5nm) particle size and the presence of a partly reducible oxide (ceria or a transition metal oxide) have a beneficial effect on the catalyst performance. The present paper R. Grisel, K-J Weststrate, A. Gluhoi and B. Nieuwenhuys from the Leiden Institute of Chemistry, Leiden University, Netherlands, *Gold Bulletin*, 2002, **35**(2), 39-45 reviews recent studies focused on understanding the specific role of the gold particle size and that of the oxide (MO). The personal viewpoint of the authors on gold catalysis is outlined. The effects of Gold particle size and of the oxidic additive are distinguished by using several alumina-supported gold catalysts having different gold particle sizes and various oxidic additives. The most active catalyst in CO oxidation is the multicomponent catalyst $Au/MgO/MnOx/Al_2O_3$ with MgO being a stabilizer for the Au particle size and MnOx being the co catalyst. This catalyst also exhibits good performance in selective oxidation of CO in a hydrogen atmosphere a reaction relevant for the development of polymer electrolyte fuel cell technology

2.2 Single Step Sol-Gel made Gold on Alumina Catalyst for Selective Reduction of NOx under Oxidizing Conditions: Effect of Gold Precursor and Reaction Conditions

E. Seker and E. Gulari, from the Chemical Engineering Department, University of Michigan, MI, USA *Applied Catalysis, A: General* 2002, **232**(1-2), 203-217 report the effect of gold precursor and reaction conditions on the catalytic activity of gold-alumina catalysts prepared by the sol-gel process. Gold catalysts prepared by the sol-gel method were the most active catalysts ever reported in the literature. The authors discovered that the final activity of gold on alumina was a strong function of the gold loading, the gold precursor and an activation procedure. The gold on alumina catalyst, prepared with 0.8 wt. % gold loading and from gold acetate, showed the highest activity. Increasing the feed oxygen concentration had many beneficial effects on the activity and also resulted in the broadening of the temperature window of activity for the 0.8 wt. % gold (acetate) on alumina catalyst. The authors found out that N2 selectivity of the catalyst was a strong function of water in the feed. The 100% N2 selectivity at peak conversion, obtained under the dry reaction conditions, decreased to ca. 58% when there was ca. 2% water in the feed.

2.3 Direct formation of Hydrogen Peroxide from H_2/O_2 using a Gold Catalyst

Supported Gold catalysts are very selective for the direct formation of hydrogen peroxide from H_2/O_2 mixtures at 2°C. (P. Landon P.J. Collier, A.J. Papworth, C.J. Kiely and G.J. Hutchings from the Department of Chemistry, Cardiff University, UK, *Chemical Communications (Cambridge, United Kingdom)*, 2002, **18**, 2058-2059).The rate of H_2O_2 synthesis is markedly increased if Gold-Palladium alloy nanoparticles are generated by the addition of Palladium.

2.4 Catalytic CO Oxidation by a Gold Nanoparticle: A Density Functional Study

Calculations are presented by N. Lopez and J.K. Norskov, K. Jens from the Center for Atomic-Scale Materials Physics, Technical University of Denmark, Lyngby, *Journal of the American Chemical Society*, 2002, **124**(38), 11262-11263, showing that an isolated Au10 cluster should be able to catalyze the CO oxidation reaction even below room temperature The extraordinary reactivity can be traced back to special reaction geometries available at small particles in combination with an enhanced ability of low coordinated gold atoms to interact with molecules from the surroundings.

2.5 Fuel-Cell Cathode Catalyst Containing Supported Platinum and Gold and Its Manufacture

The title catalyst is a particle which contains platinum and gold supported on a conductive carbon material, where the particle has a gold-rich inside and a platinum-rich outer surface. (H. Wakita and M. Hosaka from the Matsushita Electric Industrial Co., Ltd., Japan Patent no JP 2002305001, A2, 6 April 2001). The catalyst is manufactured by reducing a mixed solution containing a platinum complex and a gold complex to give a colloid solution and then treating the colloid with a conductive carbon material. Alternatively, the colloid solution is manufactured by reducing a gold complex solution to give a gold colloid solution, dissolving a platinum complex to give a mixed solution; and then reducing the solution to give a colloid solution. The catalyst has decreased amount of platinum and provides high catalytic performance.

2.6 Catalytic Role of Gold in Gold-Based Catalysts: A Density Functional Theory Study on the CO Oxidation on Gold

Gold-based catalysts have been of intense interests in recent years, being regarded as a new generation of catalysts due to their unusually high catalytic performance. For example, CO oxidation on Au/TiO_2 has been found to occur at a temperatures as low as 200 K. Despite extensive studies in the field, the microscopic mechanism of CO oxidation on gold-based catalysts remains controversial. Aiming to provide insight into the catalytic roles of gold, Z-P. Liu, P. Hu and A. Alavi from the School of Chemistry, Queen's University of Belfast, UK *Journal of the American Chemical Society* 2002, **124**(49), 14770-14779 have performed extensive d. functional theory calculations for the elementary steps in CO oxidation on gold surfaces. O atom adsorption, CO adsorption, O_2 dissociation, and CO oxidation on a series of gold surfaces, including flat surfaces, defects and small clusters, have been investigated in detail. Many transition states involved are located, and the lowest energy pathways are detected. The authors find the following: (i) the most stable site for O atom on gold is the bridge site of step edge, not a kink site; (ii) O_2 dissociation on Au (O_2.fwdarw.2Oad) is hindered by high barriers with the lowest barrier being 0.93 eV on a step edge; (iii) CO can react with at. O with a substantially lower barrier, 0.25 eV, on gold steps where CO can adsorb; (iv) CO can react with mol. O^2 on gold steps with a low barrier of 0.46 eV, which features an unsymmetrical four-centre intermediate state (O-O-CO); and (v) O_2 can adsorb on the interface of Au/TiO^2 with a reasonable chemisorption energy. On the basis of their calculations, they suggest that (i) O_2 dissociation on gold surfaces including particles cannot occur at low temps.; (ii) CO oxidation on gold/inactive-materials occurs on gold steps via a two-step mechanism: $CO+O_2$.fwdarw.CO_2+O, and $CO+O$.fwdarw.CO_2; and (iii) CO oxidation on gold/active-materials also follows the two-step mechanism with reactions occurring at the interface.

3 Chemistry

3.1 Enhancement of Magneto-Optical Effects in Magnetite Nanocrystals Near Gold Surfaces

MCD was measured at Langmuir-Blodgett films of magnetite (Fe_3O_4) nanocrystals. G. Shemer and G. Markovich from the School of Chemistry, Tel Aviv University, Israel, *Journal of Physical Chemistry B*, 2002, **106**(36), 9195-9197. The measurements of the effect were preformed in 2 different configurations, transmission and reflection. When a nanocrystal monolayer was deposited on a rough gold surface, the MCD signal was enhanced significantly in comparison to the signal obtained for a monolayer deposited on a hydrophobic glass substrate. The effect is sharply dependent on the separation distance of the magnetite monolayer from the gold surface. This surface enhanced magneto-optical (SEMO) effect is probably caused by the enhancement of the electric field component of the electromagnetic waves at rough features of the gold surface.

3.2 Structural Investigation of Monolayers Prepared by Deposition of $(Ch_3s)_2$ on the (111) Face of Single-Crystal Gold

Although self-assembled monolayers made of long chains of n-alkanethiols [$CH_3(CH_2)n$-$_1SH$] on Au(111) were extensively studied in the past, the driving forces behind the appearance of the (3 .times. 2.sqroot.3) superlattice observed at full coverage are still not completely understood. To focus on the role played by the S headgroup minimizing the interactions between chains and to prevent a possible x-ray-induced damage, M.F. Danisman, L. Casalis, G. Bracco and G. Scoles

from the Department of Chemistry, Princeton University, NJ, USA , *Journal of Physical Chemistry B*, 2002, **106**(45), 11771-11777, carried out a He atom diffraction study of the adsorption of the shortest (n = 1) thiol radical, obtained by dissociative adsorption of $(CH_3S)_2$, on the Au(111) surface.

3.3 Sensing Strategy for Lithium Ion Based on Gold Nanoparticles

The detection of Li+ is currently in demand for both biomedical and industrial applications. The authors, S.O. Obare, R.E. Hollowell and C.J. Murphy from the Department of Chemistry and Biochemistry, University of South Carolina, Columbia, USA, *Langmuir*, 2002, **18**(26), 10407-10410 report the functionalization of 4 nm gold particles with a 1,10-phenanthroline ligand that binds selectively to Li+. The ligand binds to Li+ by forming a 2:1 ligand-metal complex, causing gold nanoparticles to aggregate. Gold nanoparticle aggregation causes a shift in the extinction spectrum with a concomitant colour change, providing a useful optical method of detecting Li+ in aqueous solution.

4 Electrochemistry

4.1 Photoelectrochemical Currents at Gold Electrode at Negative Potentials

This paper by G.Y .Kolbasov; V.S. Kublanovskii, T.A. Taranets, K.I. Litovchenko from the National Academy of Sciences of Ukraine, Kiev, 252142, *Russian Journal of Electrochemistry (Translation of Elektrokhimiya)* 2002, **38**(6), 651- studies the photoelectrochemical and electrochemical processes at ground, polished, and etched surfaces of gold in a 0.5M $NaClO_4$ solution.

4.2 Anodic Dissolution of Gold in Alkaline Solutions Containing Thiourea, Thiosulfate and Sulfite Ions

Gold dissolves electrochemically in alkaline solutions containing ligands to form complex gold ions. Therefore, selective leaching of noble metals is expected without dissolution of base metals such as steels, aluminum alloys in scrap treatment. Gold electrodes were investigated by M. Okido, M. Ishikawa and L. Chai from the Centre for Integrated Research in Science and Engineering, Nagoya University, Japan, *Transactions of Nonferrous Metals Society of China* 2002, **12**(3), 519-523 using linear sweep voltammetry, EQCM method and potentiostatic electrolysis in alkaline solutions containing thiourea, Na_2SO_3 and $Na_2S_2O_3$. The solution composition and electrode potential affect the gold dissolution, rate and current efficiency. The gold dissolved from the anode electrode forms complex ions, suspension particles as compounds precipitate and deposits on the cathode electrode as a metal. Anodic efficiency for gold dissolution is between 10% and 22%. This is caused by the oxidation decomposition of sulfite ions and thiourea. The stability of the alkaline solution containing these elements was also established by capillary electrophoresis technique.

4.3 Electrochemical and Surface-Enhanced Raman Spectroscopy Studies of 4-Phenylpyridine Adsorption at the Gold/Solution Interface

The adsorption of 4-phenylpyridine (4-PhPy) on the gold electrode was examined using conventional electrochemical techniques such as cyclic voltammetry, impedance measurements and surface enhanced Raman spectroscopy (SERS) in a wide range of electrode potentials. (M. Jurkiewicz-Herbich; R. Slojkowska, K. Zawada and J. Bukowska from the Department of Chemistry, University of Warsaw, Poland, *Electrochimica Acta* 2002, **47**(15), 2429-2434). Electrochemical results indicate the strong adsorption of 4-Phpy molecules, particularly at the positively charged gold electrode. The wide shoulder of capacity close to the pzc suggests that the composition and/or the structure of 4-Phpy monolayer changed with the sign of the surface charge on the electrode. Investigations of integrity of the adsorbed layer, however, indicated that adsorbed molecules do not form a tight, compact monolayer even in the case of adsorption from saturated. Solution SERS spectra provided evidence for gradual, potential-induced reorientation of the mol. plane with respect to the surface, from nearly vertical in the negatively charged electrode, to more flat at the positively charged metal surface Electronics and Sensors.

4.4 A New High Speed Acid Gold Process, Developed and Characterized for Connector Market

This paper describes a new high speed cobalt hardened bright acid gold. (L. Chalumeau, J. Gonzalez, C. Leclere, M. Limayrac, M. Wery and J. Pagetti from Engelhard-CLAL, Noisy Le Sec, France, *Proceedings – AESF SUR/FIN Annual International Technical Conference*, 2002 500-507). Correlation between the physical properties of the deposition and the composition were observed. The evaluation was undertaken at a range of high current densities and the increases obtained reported. Different techniques of analysis such as Glow Discharge Mass Spectrometry were used and are explained in the paper.

4.5 In-Situ SERS Experiments during the Electrodeposition of Gold in the Presence of Benzyldimethylphenylammonium Chloride

Hydrogen incorporation is one of the main problems encountered in electroforming and electroplating processes and can result in serious material embrittlement. Use of organic additives reduces hydrogen incorporation efficiently in electrodeposition of gold from neutral cyanoaurate baths. The authors A. Fanigliulo and B. Bozzini from the University of Lecce, Italy, *Journal of Electroanalytical Chemistry* 2002, **530**(1-2), 53-62 report the results of: (i) in-situ surface enhanced Raman spectroscopy experiments; supported by (ii) electrochemical measurements (cyclic voltammetry, differential capacitance); and (iii) GC-MS analyses, relevant to electrodeposition of gold from a $KAu(CN)_2$ aqueous solution, containing benzyldimethylphenylammonium chloride (BDMPAC). The cathodic co-adsorption of cyanide and the quaternary ammonium salt causes a remarkable depolarization of the metal deposition. The results obtained match well with the hypothesis of two surface reactions, taking place at potentials more neg. than -1300 mV vs. Ag|AgCl, which involve the additive and bring about the consumption of both hydrogen and cyanide adsorbed on the electrode. Depolarizing effects and reduced hydrogen incorporation accomplished using BDMPAC can thus be related to its hydrogen and cyanide scavenging action.

5 Electronics and Sensors

5.1 Issues with Gold Electroplating for Microelectromechanical System Applications

Electro-plated gold films are used extensively in packaging of MEM sensors to make connections to signal conditioning electronics. Over the past two years, production batches from various vendors, gold plated substrates, failed an accelerated aging qualification test. In this test, the authors, C.A. Kondoleon and T.F. Marinis, from The Charles Stark Draper Laboratory, Cambridge, MA. USA, *Materials Research Society Symposium Proceedings* 2002, **687** (Materials Science of Microelectromechanical Systems (MEMS) Devices IV), 143-148 took 0.0025 [mm] diameter aluminum wires and ultrasonically welded them to the film. These were then aged at 120°C for 48 h, and pulled to destruction. The criterion for passing this test was that the wires should break both before and after aging. In the defective lots, the wires lifted off of the gold film after aging. Analysis of these defective films by SEM, Auger, and TOF-SIMS suggested that residues, deposited from the plating bath, concentrated beneath the bond as the gold and aluminum reacted to form an inter-metallic compound during aging. A combination, etch and cleaning treatment was developed for defective substrates, which removed a sufficient amount of residues from the gold to pass the qualification test.

5.2 Probing Interactions in Mesoscopic Gold Wires

This is a review by F. Pierre, H. Pothier, D. Esteve, M.H. Devoret, A.B. Gougam, and N.O. Birge from the Commissariat a l'Energie Atomique, France, *NATO Science Series, II: Mathematics, Physics and Chemistry* 2001, **50**(Kondo Effect and Dephasing in Low-Dimensional Metallic Systems), 119-132 which demonstrates that the energy exchange rates between electrons in mesoscopic gold wires have the same energy dependence as observed in copper and have an even higher magnitude? The origin of this effect was evaluated by performing resistance measurements on samples fabricated similarly. The logarithmic dependence of the resistance, the negative magnetoresistance at large field and temperature dependence of the phase coherence time, which is constant between 8 and 0.5 K and increases at lower temperature, indicate magnetic impurities, which might mediate electron-electron interactions.

5.3 Preferential Adhesion of Gold Nanoparticles using Lithographically Patterned Substrates

This paper by J. Pihl, M.S. Kabir and S.H.M. Persson from the Department of Microelectronics and Nanoscience, Chalmers University of Technology, Goeteborg, Sweden, *Materials Research Society Symposium Proceedings* 2002, **705**(Nanopatterning: From Ultralarge-Scale Integration to Biotechnology), 199-203 describes a method of aligning small amounts of colloidal particles between narrowly spaced electrodes using a combination of conventional nanofabrication and self-assembled monolayers. Transport measurements were performed on several devices.

5.4 Pulse Plating of Gold-Tin Alloys for Microelectronic and Optoelectronic Applications

Gold-30 at.% Tin eutectic solders are used for packaging microelectronic and optoelectronic devices, due to their excellent thermal and mechanical properties and relatively low melting or reflow temperature (280.degree). Electroplating is a cost effective alternative to current commercial solder deposition processes, such as solder preforms and evaporation. A Co-electroplating process for depositing Au-Sn alloys, from a slightly acidic, chloride-based solution using pulsed currents, onto metalized ceramic and semiconductor substrates was developed by A. He, B. Djurfors, S. Akhlaghi and D.G. Ivey from the Department of Chemical and Materials Engineering, University of Alberta, *Canada Proceedings* – AESF SUR/FIN *Annual International Technical Conference*, 2002, 954-966. Two separate Au-Sn compositions, 15 at.% Sn and 50 at.% Sn, can be deposited under appropriate plating conditions, i.e., c.d., and pulse on/off time and duration. These compositions, according to the Au-Sn phase diagram, correspond to Au_5Sn and AuSn,

respectively by using multiple current pulses and varying their duration, it is possible to deposit a composite solder structure with an overall composition ranging from 15-50 at.% Sn, including the important eutectic composition. Plating results for both unpatterned and patterned (with photoresist) substrates are presented. All substrates were metalized with Ti/Au or Ti/Mo/Au, to provide a gold seed layer for electroplating

5.5 Reductions in the Thickness of Gold Layers for Connector Applications by Utilizing Undercoats of Electrolytic Nickel Phosphorous Alloys

Gold plating has usually been the most expensive part of plating of an electrical connector. The use of an electrolytic nickel-phosphorous alloy underlayer that offers opportunities to reduce the gold thickness is described by S. Burling, M. Wild and S. Teague from Engelhard-CLAL UK Ltd, Gloucestershire, UK, *Proceedings – AESF SUR/FIN Annual International Technical Conference*, 2002 493-499. Deposition in both high-speed and barrel applications, as well as the properties of the deposits obtained are described. The use of glow discharge mass spectroscopy for analysis is described.

6 Medical and Dental

6.1 The Direct Electrochemistry of Folic Acid at a 2-Mercaptobenzothiazole Self-Assembled Gold Electrode

A pair of well-defined redox waves of folic acid at a 2-mercaptobenzothiazole self-assembled Au electrode (MBT/SAM/Au) was achieved by Q. Wan and N. Yang from the Department of Chemistry and Environmental Engineering, Hubei Normal University, Huangshi Peoples Republic of China, *Journal of Electroanalytical Chemistry*, 2002, **527**(1-2), 131-136. Folic acid can bind strongly to MBT/SAM/Au and form a closely packed monolayer, whose average electron transfer rate is 0.085 s-1 with a two-electron/two proton transfer, a maximum surface coverage of 2.8 times 10-10 mol cm-2, an adsorption equivalent constant of (4.0 +- 0.2).times.105 l mol-1, and an electrode reaction resistance of 12489 OMEGA. The oxidation peak currents achieved on MBT/SAM/Au vary linearly with the logarithm of the content of folic acid at 8.0 times 10-9-1.0 times 10-6 mol L-1. The detection limit is 4.0 times 10-9 mol L-1. This can be used to detect folic acid.

6.2 Effects of Gold Coating of Coronary Stents on Neointimal Proliferation following Stent Implantation

Experimental studies suggest a reduced neointimal tissue proliferation in vascular stainless steel stents coated with gold. This prospective multicenter trial evaluated the impact of gold coating on neointimal tissue proliferation in patients undergoing elective stent implantation.(J. vom Dahl, P.K. Haager, E. Grube, M. Gross, C. Beythien, E.P. Kromer, N. Cattelaens, C.W. Hamm, R. Hoffmann, T. Reineke and H.G. Klues from the Medizinische Klinik I, Universitatsklinikum der RWTH Aachen, Aachen, Germany, *American Journal of Cardiology*, 2002, **89**(7), 801-805). The primary end point was the in-stent tissue proliferation measured by intravascular ultrasound at 6 mo comparing stents of identical design with or without gold coating (Inflow).

7 Metallurgy, Materials and Coatings

7.1 Preparation of Gold Powders by Means of Redox-Active Extractive Systems

The solvent extraction of gold by using two S-decyldithizone derivatives was studied in which partial precipitation of the gold and oxidation of the extractants were observed by M.G. Sanchez-Loredo, A. Robledo-Cabrera and M. Grote from the Instituto de Metalurgia, Universidad Autonoma de San Luis Potosi, Mexico, *Materials Chemistry and Physics*, 2002, **76**(3), 279-284. Gold was recovered from the loaded organic phases by reduction as fine particles, and the extractants can be reduced and fully regenerated. The efficiency of extractant regeneration increased with increasing ascorbic acid concentration. In the case of reduction with sodium borohydride, the highest reduction efficiency was achieved by using an alkaline borohydride solution. A SEM method has been used to characterize the precipitated gold powders. The carboxylic group on one of the aromatic rings of the substituted S-decyldithizone greatly influences the morpholology and size of the produced gold particles.

7.2 Texture Development and Twinning in Polycrystalline Gold Thin Films

Gold thin films have a {111} texture component that strengthens during heating. This texture can be affected by the formation of twins, which may be influenced by the substrate material. Gold thin films were evaporated. onto rock salt and glass substrates, and incrementally annealed without removal from the substrate by R.E. Cefalu and A.H. King from the School of Materials Engineering, Purdue University, IN, USA, *Materials Research Society Symposium Proceedings*, 2002, **721**(Magnetic and Electronic Films-Microstructure, Texture and Application to Data Storage),

31-36. The texture was mapped using an area detector x-ray diffractometer. The films showed a primary {111} fiber texture and a secondary {200} fiber texture on both substrates with the addition of a {511} fiber texture component, which is much more pronounced on rock salt than on other substrates. The {511} surface normal derives from a twin rotation, showing that there is more twinning on rock salt than on glass although there is no lattice matching between the rock salt and gold.

7.3 Dielectric Properties of Gold Nanoparticles Cross-Linked with Dithiol Spacers

Solid materials based on gold nanoparticles cross-linked with dithiol spacer molecules were prepared and their dielectric properties examined. (P. Drake and I. Youngs, from the Structures and Materials Centre, QinetiQ, Farnborough, UK, *Materials Science and Technology*, 2002, **18**(7), 772-776). The gold nanoparticles were prepared via a standard toluene/water two-phase system using sodium borohydride as the reducing agent. Two different sized nanoparticle colloids were produced, 4.8 and 1.2 nm diameter These were cross-linked with 2 dithiol compounds, 1,5-pentanedithiol and 1,9-nonanedithiol. The combination of 2 different size colloids and 2 different spacer molecules led to 4 final materials. The dielectric properties of the 4 materials were investigated using a broadband dielectric spectrometer in the frequency range of 1 Hz to 10 MHz and the temperature range 123-373 K. The imaginary component of the dielectric loss factor is presented for each material over the frequency and temperature range quoted. The 1 Hz room temp. cond. for each material was between 0.1 and 7.2 .mu.S cm^{-1}. The temperature dependence of the cond. followed that predicted for a non-metallic activated electron hopping mechanism with the electrostatic activation energy for each material being between 0.034 and 0.120 eV. These were calculated by applying the simple Arrhenius-based equation first described by Neugebauer.

7.4 Preparation and Isolation of Gold Nanoparticles Coated with a Stabilizer and Sol-Gel Compatible Agent

A technique is presented by R. Trbojevich, N. Pellegri, A. Frattini, O. de Sanctis, P.J. Morais and R.M. Almeida from the Laboratorio de Materiales Ceramicos, Rosario, *Journal of Materials Research*, 2002, **17**(8), 1973-1980 that brings together the advantage of the reverse micelle technique to control particle growth and efficiency of the amino silanes as sol-gel-compatible surface modifiers. The silane, 3-(2-aminoethylaminopropyl)trimethoxysilane, is far from being a passive agent in the formation of the gold particles and strongly modifies their growth in the reverse micelle. The silane allows the gold particles to keep their individual properties unaltered throughout the process, which ends with their incorporations into a SiO_2-20 TiO_2 sol-gel glass thin film.

7.5 Effects of Trace added Calcium or Palladium on Annealing Characteristics of Cold-Worked Pure Gold

This study by S. Mitoma, I. Itabashi, S. Takaura and H. Osono, from Tanaka Denshi Kogyo K.K., Tokyo, Japan, *Nippon Kinzoku Gakkaishi* 2002, **66**(7), 754-759, investigates the influence of trace added Ca or Pd on the annealing characteristics of cold-worked pure gold. The electrical resistance of Au-0.018 at.% Pd, Au-0.020 at.% Ca, and pure gold (99.999 mass%) were measured in the temperature range from room temp. to 873 K. The samples were annealed at temperatures where peculiar changes in electrical resistivity were observed and subsequently investigated through tensile tests, metallography observations, and transmission electron microscopy. The electrical resistivity of Au-0.018 at.% Pd and pure Au decreased rapidly between 340 K and 390 K. Within this temperature range, mechanical properties of the specimen also changed rapidly toward re-crystallization. The electrical resistivity of Au-0.020 at.% Ca decreased in 3 gradual steps between 410 K and 750 K. The mechanical properties also changed gradually over this temperature range. Recrystallization structures were observed at 750 K. Whereas the recovery and recrystallization of cold-worked pure Au was unaffected by the addition of trace Pd, these processes were significantly affected by trace added Ca. This appears to be related to the fixing of dislocation with Ca atoms and the strong interaction between vacancies and calcium atoms.

8 Nanotechnology

8.1 Propulsion of Gold Nanoparticles on Optical Waveguides

The optimization of K ion-exchanged optical waveguides in glass for evanescent field propulsion of colloidal gold nanoparticles is reported by L.N. Ng, B.J. Luff, M.N. Zervas and J.S.Wilkinson from the Optoelectronics Research Centre, University of Southampton, UK, *Optics Communications* 2002, **208**(1-3), 117-124. Velocity dependence upon ion-exchange parameters is given and a maximum velocity of 8 .mu.m/s was achieved for 10-40 nm radius particles with 500 mW modal power at 1.047 .mu.m.

8.2 A Versatile Surface Modification Scheme for Attaching Metal Nanoparticles onto Gold: Characterization by Electrochemical Infrared Spectroscopy

A simple method for preparing metal nanoparticle films immobilized on gold substrates is described by S. Park and M.J. Weaver from the Department of Chemistry, Purdue University, West Lafayette, IN, USA, *Journal of Physical Chemistry B*, 2002, **106**(34), 8667-8670. A variety of nanoparticle films are characterized by electrochemical IR reflection-absorption spectroscopy (EC-IRAS) in which the anomalous "negative-absorbance" properties commonly observed in metal particle arrays can be completely controlled. Such "anti-absorbance" .nu.CO band components obfuscating the EC-IRAS data interpretation are associated with the complex dielectric behaviour induced by metal nanoparticles aggregates. To achieve a well distributed metal nanoparticle array, the substrates were pre-treated with 3-mercaptopropyltrimethoxysilane before anchoring gold, platinum or platinum-ruthenium alloy nanoparticles on the gold substrates. The prepared nanoparticle films displayed excellent electrochemical properties implying facile electronic communication through the organic glue matrix between the nanoparticle arrays and the gold substrates. Coating of the gold nanoparticle arrays with platinum via copper under potential deposition (UPD) steps furthermore demonstrates optimal electronic response between the nanoparticle arrays and the underlying substrate. These findings will facilitate better nanoparticle analysis by electrochemical and optical spectroscopic means.

8.3 Evaluation of the Change in the Morphology of Gold Nanoparticles During Sintering

The morphology changes of agglomerates consisting of nanometre primary gold particles were studied experimentally and theoretically by K. Nakaso, M. Shimada, K. Okuyama and K. Deppert from the Department of Chemical Engineering, Hiroshima University, Japan, *Journal of Aerosol Science*, 2002, **33**(7), 1061-1074. Gold aerosol nanoparticles were produced by using the evaporation/condensation method, and the change in agglomerate size by reheating was examined experimentally using a tandem DMA setup. Numerical calculations based on two extreme mechanisms to reshape agglomerates, i.e., subsequent coalescence of primary particles and subsequent rearrangement of primary particles, were carried out. By comparison with the experimental results, the sintering time and rate constant of restructuring were obtained. Using these values, the change in particle size for different generation conditions was calculated. The change in morphology of agglomerates can be explained from the comparison of the experimental results with the theoretical calculations. Agglomerates with smaller primary particles compact mainly by the subsequent coalescence of primary particles, while agglomerates with larger primary particles compact mainly by a re-arrangement of primary particles.

8.4 Growth of Gold Clusters into Nanoparticles in a Solution Following Laser-Induced Fragmentation

Colloidal gold nanoparticles having an average diameter of 8 nm were prepared by laser ablation at 1064 nm of a gold metal plate in an aqueous solution of sodium dodecyl sulfate (SDS) and were subjected to fragmentation under irradiation of a pulsed laser at 532 nm. F. Mafune, J. Kohno, Y. Takeda and T. Kondow from the Cluster Research Laboratory, Toyota Technological Institute, Japan, *Journal of Physical Chemistry B*, 2002, **106**(34), 8555-8561. Gold clusters exhibiting no significant optical absorption in the visible wavelength region were produced in a solution, together with nanoparticles. UV-visible optical absorption spectroscopy revealed that the gold clusters grow gradually through attachment to the nanoparticles and through mutual aggregation. The growth processes depend crucially on the concentration of SDS in the aqueous solution of nanoparticles.

8.5 Gold Nanoparticles

A review by *Y. Nagasaki, Yukio* from the Faculty of Engineering, Tokyo University of Science, *Japan Kagaku Furontia*, 2002, **7** (Nanomateriaru Saizensen), 162-166 on preparation of gold nanoparticles and their application for biology detection and molecule recognition.

8.6 Digestive Ripening of Thiolated Gold Nanoparticles: The Effect of Alkyl Chain Length

Digestive ripening, heating a colloidal suspension at or near the solvent b.p. in the presence of a surface-active ligand, was applied to polydisperse colloidal gold in toluene using a series of alkylthiols, viz., octyl-, decyl-, dodecyl-, and hexadecylthiols. (B.L.V. Prasad, S.I. Stoeva, C.M. Sorensen and K.J. Klabunde, from the Department of Chemistry and Department of Physics, Kansas State University, Manhattan, USA, *Langmuir*, 2002, **18**(20), 7515-7520). In all the instances, digestive ripening significantly reduced the average particle size and polydispersity. All the colloids remain suspended in solution above 80°C, but at room temperature the tendency to form 3D superlattices and precipitate increased with declining alkyl chain length. An example of this is, using octanethiol as the ligand which makes the colloids aggregate into big 3D superlattices and precipitate; decane- and dodecanethiol also produce precipitated 3D superlattices along with separate particles, while hexadecanethiol-coated particles remain well separated from each other. The optical spectra at room

temperature reveal, apart from the gold plasmon band at 530 nm, a large tail above 700 nm for gold-octanethiol and gold-decanethiol cases and a shoulder at 630 nm for gold-dodecanethiol attributed to the superlattices. Gold-hexadecanethiol, on the other hand, shows only the gold plasmon band as expected from separate particles. However, at higher temperatures only the gold plasmon band is observed for all the colloids indicating the dissolution of the superlattices. The aggregation of the particles into 3D superlattices or their stability as a colloidal suspension is explained on the basis of decreasing van der Waals attraction between the gold nanoparticles as the separation between them is increased through the alkyl chain length of the capping ligand from octyl to hexadecyl.

8.7 Vapour Sensing using Surface Functionalized Gold Nanoparticles

The electrical and optical response of thin films of surface functionalized nanoparticles upon exposure to various chemical vapours was studied by H.L. Zhang, S.D. Evans, J.R. Henderson, R.E. Miles and T.H. Shen from the Department of Physics and Astronomy, University of Leeds, UK, *Nanotechnology*, 2002, **13**(3), 439-444. The electric response to chemical vapours adsorbed on the various nanoparticle films varied markedly and was detected by the surface functional groups. Ellipsometric studies revealed that the film thickness increased during exposure to the chemical vapours. These thickness changes of the films correlate with the changes in electrical conductance. Two physical effects are believed to play a role in detecting these conductance changes. Under high partial pressure, the change in nanoparticle core-core separation is the main contribution to the change in conductance and generally leads to a reduction in the conductance. However, for relatively low partial pressures the adsorption of vapour molecules leads to permittivity changes that tend to increase the conductance.

8.8 Increased Sensitivity of Surface Plasmon Resonance of Gold Nanoshells Compared to that of Gold Solid Colloids in Response to Environmental Changes

Gold nanoshells were synthesized by reacting aqueous $HAuCl_4$ solutions with solid templates such as silver nanoparticles. (Y. Sun and Y. Xia from the Department of Chemistry, University of Washington, Seattle, WA, USA, *Analytical Chemistry*, 2002, **74**(20), 5297-5305). The morphology, void space, and wall thickness of these hollow nanostructures were all detected by the templates, which were completely converted into solution species during the replacement reaction. The surface plasmon peaks of these gold nanoshells were considerably red shifted as compared to gold solid colloids having approximately the same dimensions. The surface plasmon resonance of gold nanoshells exhibited a much more sensitive response toward environmental changes even when compared with solid colloids with a mean size much smaller than that of gold nanoshells. For example, the sensitivity factor (i.e., the shift in peak position per unit change in the refractive index of the surrounding medium) was 408.8, 60.0, and 70.9 nm per refractive index unit for gold nanoshells with a mean diameter of 50 nm and wall thickness of 4.5 nm, gold solid colloids of 50 nm in diameter, and gold solid colloids of 30 nm in diameter, respectively. The formation of alkanethiolate self-assembled monolayers on their surfaces caused the plasmon peaks to red shift by 3.0 nm per methylene unit for gold nanoshells and 0.2 nm per methylene unit for solid colloids with a mean size of 50 nm. Such enhanced sensitivities should make gold nanoshells particularly useful as optical probes for chemical or biological binding events at solid-liquid interfaces

8.9 Synthesis and Characterization of Gold-Silica Nanoparticles Incorporating a Mercaptosilane Core-Shell Interface

The first synthesis and characterization of gold-SiO_2 core-shell nanoparticles with a mercaptosilane interface between the core and shell silicas is reported by M.Y. Chen and A. Katz from the Department of Chemical Engineering, University of California at Berkeley, USA, *Langmuir*, 2002, **18**(22), 8566-8572. These nanoparticles exploit the strong interaction between thiols and gold to create a well-defined interface of functional group organization between core and shell. This requires the synthesis of a mercaptosilane monolayer on the colloidal Au surface, which is indirectly accomplished using a thioester (1) as a protected precursor to 3- mercaptopropyltriethoxysilane. (1) binds to gold, undergoes sol-gel hydrolysis and condensation, and subsequently deprotects to a thiol via gold-catalyzed thioester hydrolysis. This process results in a monolayer of condensed mercaptosilane on the nanoparticle surface without inducing colloidal instability, which was observed upon direct mercaptosilane addition at the same surface coverage. Similar results were obtained for the previously reported thioester (2) which also binds to gold and deprotects in the bound state, as does (1) but lacks sol-gel active functional groups. Binding experiments with (1) show that its surface-bound thioester has a significantly higher affinity to gold compared with that of (2) which is consistent with polysiloxane formation upon binding (1).

8.10 Fabrication of 2d Gold Nanowires by Self-Assembly of Gold Nanoparticles on Water Surfaces in the Presence of Surfactants

An extensive comparative transmission electron microscopy (TEM) and atomic force microscopy (AFM) study of Langmuir-Blodgett films of gold nanoparticle/dipalmitoylphosphatidylcholine (DPPC) mixtures transferred onto solid substrates at different surface pressures has been conducted by T. Hassenkam, K. Norgaard, L. Iversen, C.J. Kiely, M. Brust, T. Bjornholm, from the Nano-Science Center, The University of Copenhagen, *Advanced Materials (Weinheim, Germany)*, 2002, **14**(16), 1126-1130 to monitor the process of nanostructure formation. Dodecanethiol-capped gold nanoparticles of 1.5-3 nm diameter were prepared according to a well-established two-phase liq./liq. reduction route. The surfactant systems at the air/water interface can be used as 2D templates for the self-assembly of metallic nanostructures. The complexity of the surfactant phase behaviour may be used to regulate the formation of structures on the micrometer scale, while their molecular structure can influence assembly processes on the nanometer scale. The dodecanethiol-capped gold nanoparticles of 1.5-3 nm diameter in a matrix of DPPC, at the air/water interface, self-assemble into a maze of continuous gold nanowires resembling a molecular electronic circuit board. These nanostructures can to some extent be controlled by adjusting the parameters that affect the self-assembly process.

9 Refining

9.1 Ultrafine Milling for the Processing of Gold-Bearing Sulphides

H. Yang, Y. Hu, W. Ao, G. Qiu and D. Wang from the Department of Mineral Engineering, Central South University, Changsha, Peoples Republic of China, *Rare Metals (Beijing, China)*, 2002, **21**(2), 133-136, used ultrafine milling technology to treat gold-bearing sulfides and investigated the effects of minerals size, milling time, liquid/solid ratio, NaCN consumption and leaching aid on the leaching rate of gold. The shorter treatment time, decrease in NaCN consumption of 60% and increase of gold leaching rate of 15% can be obtained by using the ultrafine milling technolology compared with traditional cyanide leaching. Potential exists for the process to form the basis for an economically viable, high-efficiency process for treatment of gold-bearing sulfides.

9.2 Recovery of Gold in Carbon-in-Pulp Process by Elution and Extraction

This invention patented by B.R. Green and R.L. Paul from Mintek, South Africa, WO 2002077302, A2, 20 March 2002, investigates the recovery of gold in carbon pulp. The gold in solution from elution of the loaded carbon sorbent is concentrated and recovered by: (a) adsorbing the Gold-cyanide complex on anion-exchange resin of typically strong-base type; (b) stripping the gold from the loaded resin to obtain high gold concentration in solution, and (c) precipitating the gold in a storable vessel for secure further processing with decreased losses in handling. The gold in carbon-in-pulp process is typically eluted using alc. or aqueous Zn cyanide, NH_3 thiocyanate, or thiourea. The gold in concentrated solution is optionally precipitated as a mixture of gold and gold sulphide, or is removed by cementation on Copper or Aluminium powder.

9.3 Extraction of Copper and Gold by the Mixture of Tributylphosphate and Diphenylthiourea from Thiocyanate Solutions

The paper by A.A. Smol'kov, M.V. Belobeletskaya, M.A. Medkov and L.G. Kharlamova from the Institute of Khim, Vladivostok, Russia, *Khimicheskaya Tekhnologiya (Moscow, Russian Federation)*, 2002, **5**, 22-25 presents the study into the extraction of copper and gold from the acid solutions containing potassium thiocyanate by benzene solutions of tributylphosphate, diphenylthiourea, and their mixtures. The possible compositions of the compounds extracted are discussed along with the possibility of selective extraction of noble metals from thiocyanate solutions.

9.4 Recovery of Gold and other Precious Metals from Thiosulfate Leaching Solutions by Cementation with a Decreased Substrate Load

The gold and/or other precious metals leached with aqueous thiosulfate solution are recovered by cementation on a base metal powder, and the resulting precious metal-containing coating on the powder is dissolved to release the precious metal for separate recovery, followed by conventional processing and separation of the residual cementation powder. (R.Y. Wan from Newmont USA Limited, USA Patent No WO 2002079528, A1, 10 October 2002). The process is suitable for improved recovery of the gold and other precious metals from the Cu, Zn, Fe or similar cementation powders, especially by selective dissolution of .ltoreq.10% of the coated powder for sep. removal of nominally .gtoreq.90% of gold from the coating on particles. The loaded cementation powder is typically treated for dissolution with $(NH_4)_2CO_3$ at pH of 8-9, followed by conventional acidic dissolution and optional recycling of residual powder to the cementation stage. The process is suitable for recovery of precious metals with

decreased dissolution of the cementation powders, to improve the subsequent purification of the recovered precious metals.

9.5 Gold Extraction at the Gwynfynydd Mine, North Wales, United Kingdom: A Case Study of Environmentally Sustainable Mineral Processing within a National Park

S.C. Dominy and R.F.G. Phelps from the Mining Geology and Resource Engineering, Economic Geology Research Unit, James Cook University, Qld, Australia, *Publications of the Australasian Institute of Mining and Metallurgy*, 2002, **4/2002**(Green Processing 2002), 225-232 conducted a study on the Gwynfynydd Mine in North Wales. Due to the mine's location within a National Park certain environmental constraints were placed on the operators. Processing should take place above ground and not involve chemicals. As a result, an underground mill based on physical separation methods was constructed in response to these environmental constraints. Much of the mine discharge is related to the flow of rain water through the workings from surface openings on the reefs. Discharge from the underground milling facility was enhanced in various metals, particularly zinc, which was reduced to legally acceptable levels by using liming tanks prior to discharge into the River Mawddach. The company was required to monitor and treat all water discharged from the mine before it reached the river. The mine closed in 1999, after which tip re-processing has continued as part of an environmental remediation and gold supply program

9.6 Application of Bacterial Leaching in the Processing of Complex Gold-Lead Ores

Electrochemical processes were considered for bioleaching slurry containing galena-ore particles and Thiobacillus bacteria cells. V.I. Podolska, A.I. Ermolenko, Z.R. Ulberg and M.V. Pertsov, from Khim.-Tekhnol. Fak., Ukraine *Naukovi Visti - Natsional'nii Tekhnichnii Universitet Ukraini "Kiivs'kii Politekhnichnii Institut"*, 2002, **3**, 127-132. The microbial leaching was effective for sulphide oxidation in the galena-ore concentrates from gravity beneficiation of the ore from Muzhievo gold-ore field. Finely dispersed $PbSO_4$ (anglesite) powder was formed after bioleach processing, and was easily separated from the residual ore. The bioleaching method is recommended as a pre-treatment for the ore concentrate before conventional smelting and gold separation.

9.7 Technological Schemes for Recovery of Gold from Refractory Ores via Oxidation of Sulphides in Autoclaves

A review by I.P. Smirnov, K.M. Smirnov, Y.A. Menshikov and A.G. Martynov, from VNIIKhT, Russia, *Tsvetnye Metally (Moscow, Russian Federation)*, 2002, **6**, 20-23. The modern techniques in hydrometallurgical processing of sulphide-arsenic gold-containing ores are discussed. Various methods for using the pressure in treatment of raw materials from different deposits of Russia, CIS countries, and abroad are presented. The comparison of these results and technology parameters has allowed the authors to reveal advantages and drawbacks of the processes as well as to make conclusions and recommendations on their improvement to achieve the best results.

9.8 The Influence of a Pipe Reactor to Improve Pre-Oxidation and Gold Recovery and Lower Cyanide Consumption

The general experience in gold cyanidation research activities and plant practice is that high oxygen and cyanide concentrations improve gold leaching kinetics which in turn reduce residence time and increase throughput. An improved pre-oxidation method for the pyrrhotite-rich gold ore of the Bounty Gold Mine has increased gold recovery at lower reagent consumption rates. (S. Ellis, J. Andreazza and G. Senanayake from MAusIMM, Bounty Gold Mine, Victoria Park, Australia *Publications of the Australasian Institute of Mining and Metallurgy*, 2002, **2/2002**(Metallurgical Plant Design and Operating Strategies), 401-412) The installation of a pipe reactor, in conjunction with a Multi-Mix Systems oxygen injector, has lowered the amount of oxygen required to achieve a dissolved oxygen level target of 20 mg/L. The improvement of the pre-oxidation stage and lead nitrate solution addition has led to a reduction in the free cyanide concentration required for leaching and resulted in a decrease in cyanide consumption rate by 36% to achieve a 1-2% increase in the gold recovery.

10 General

10.1 Porcelain and Enamel Containing Gold/Silver Powder for Preserving Food Freshness

J.O. An, from S. Korea has patented (KR 2001002695 A, 16 June 1999) gold/silver powders added to porcelain compositions. These materials are claimed to prolong food freshness by using the sterilizing properties of silver/gold. At least 0.1% of gold/silver powder with 99.99% purity is added in the manufacture of porcelain. For enamels, at least 4% of silver/gold solution with 99.99% purity is added.

10.2 Laminated Floor Material using Gold or Silver and Process for Producing the Same

O.J. Kwon and Y.G. Byun from LG Chemical Co., Ltd., S. Korea Patent no KR 2000072510,A, 7 September 2000 patented a laminated floor material using gold or silver having excellent heat and electric conduction, antimicrobial and moth-proof properties. The flooring contains powdery gold or silver in the top layer of the surface layers and/or the back functional layer of back sheet layers, wherein the top layer of the surface layers comprises an oil or aqueous liquid phase containing 0.11-3.4 wt% of the powdery gold or silver, and the back functional layer comprises an oil or aqueous liquid phase containing 60-80 wt% of the powdery gold or silver.

10.3 Relativistic Effects in Properties of Gold

A review by P. Schwerdtfeger from the Department of Chemistry, University of Auckland, Auckland, N.Z. *Heteroatom Chemistry*, 2002, **13**(6), 578-584. Gold often shows unusual and sometimes surprising chemical and physical properties compared to its lighter group 11 elements (gold anomaly). Pyykko and co-workers demonstrated in the mid seventies that this is due to effects from special relativity. Recent work in this field indeed indicates that the chemical and physics of gold is dominated by relativistic effects.

10.4 Ion Exchange Resins in the Gold Industry

A review by V.S.T. Ciminelli from the Department of Metallurgical and Materials Engineering at Universidade Federal de Minas Gerais, *Brazil, JOM*, 2002, **54**(10), 35-36. The application of ion exchange (IX) resins in gold metallurgy is reviewed in three main contexts. The first one focuses on the use of the IX resins for the concentration and recovery of gold from leach pulps or solutions. The resins appear as an alternative to activated C, the typical gold adsorbent from dilute cyanide solutions. The second situation is that of cyanide recovery from barrens, a procedure strongly motivated by the increasing environmental restrictions on the use of cyanide. Recovery decreases the risk of spills by reducing the transport of new reagent and cyanide loading in tailing ponds. Finally, the use of resins for gold recovery from non-cyanide leach pulps is reviewed.

10.5 Study on Microwave-Resistant Liquid Gold for Porcelain

The microwave-resistant liquid gold were prepared, and the effects of the action of composite modifying agent, the yellow agent and the rosin on the properties of liquid gold were studied by J. Chen, Y. Deng, H. Chen, J. Chen and B. Peng from the Hunan Xiang Ceramics Science & Art Co. Ltd., Peoples Republic of China, *Taoci Kexue Yu Yishu*, 2002, **36**(2), 6-7. The prepared microwave-resistant liquid gold can be fired between 750°C and 850°C.

10.6 Research on Ceramics Screen Printing Gold Colloids

A review by H. Chen, J. Chen, Y. Deng and B. Peng from the Hunan Xiang Ceramics Science & Art Co. Ltd, Peoples Republic of China, *Taoci Kexue Yu Yishu*, 2002, **36**(2), 8-10; The ceramics screen printing gold colloids were prepared by carefully selecting the kind and amounts of resin, pigment, and colloids of metals. A review with references is presented.